



Soil Architecture and Preferential Flow across Scales

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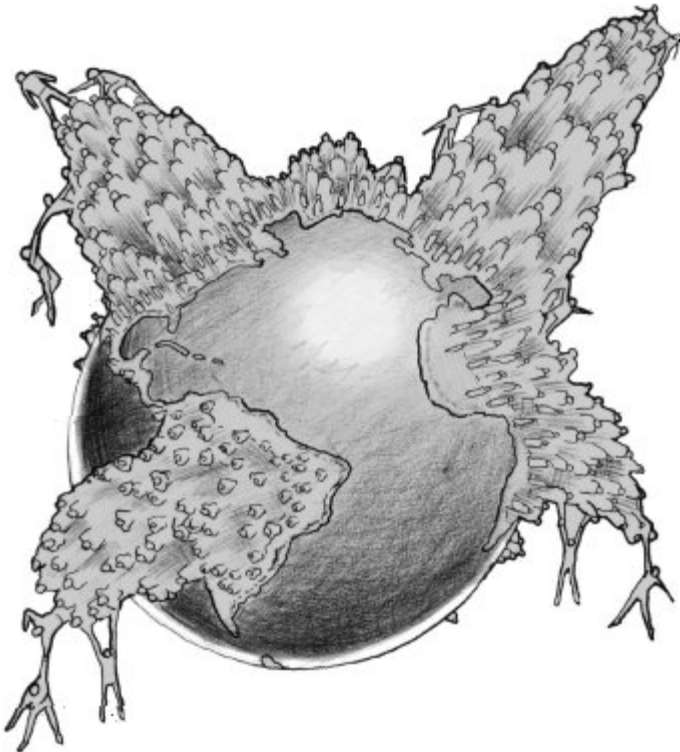


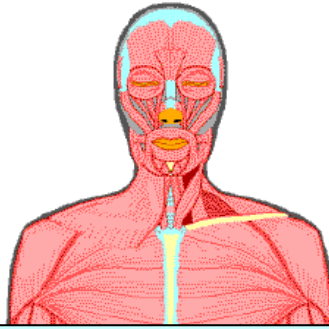
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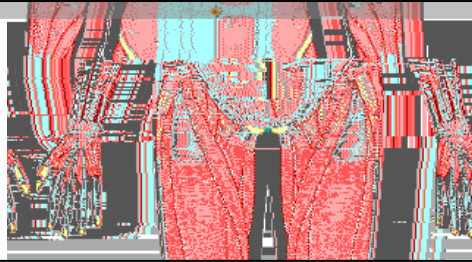
Anthropocene

- *A new geological epoch in which humankind has emerged as a globally significant, and potentially intelligent, force capable of reshaping the face of the planet (Clark et al., 2004).*

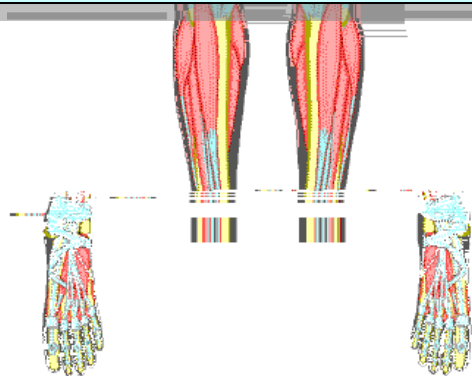




Architecture: Body Skeleton



Flow: Blood and Oxygen





If you don't see it, it doesn't matter?!

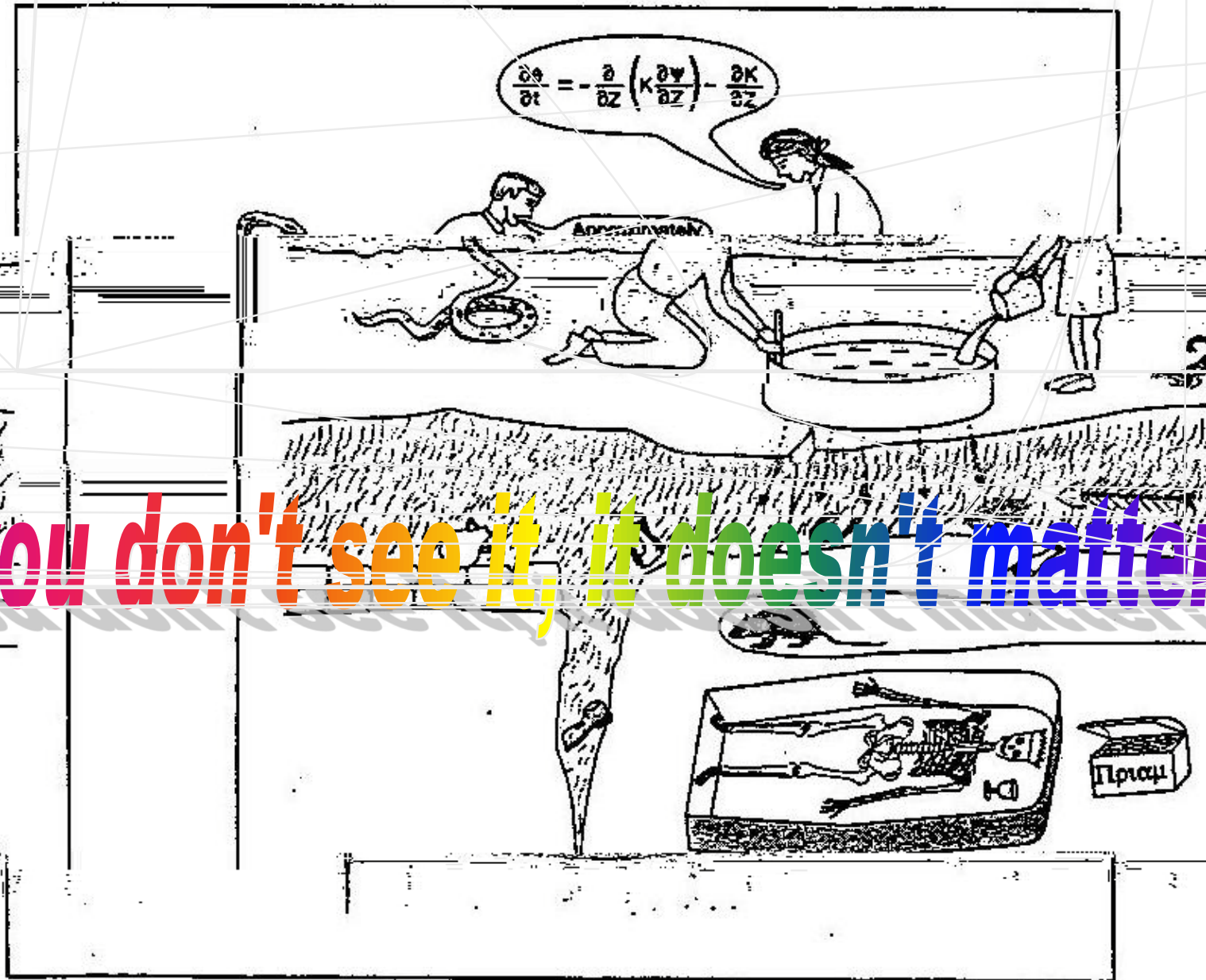
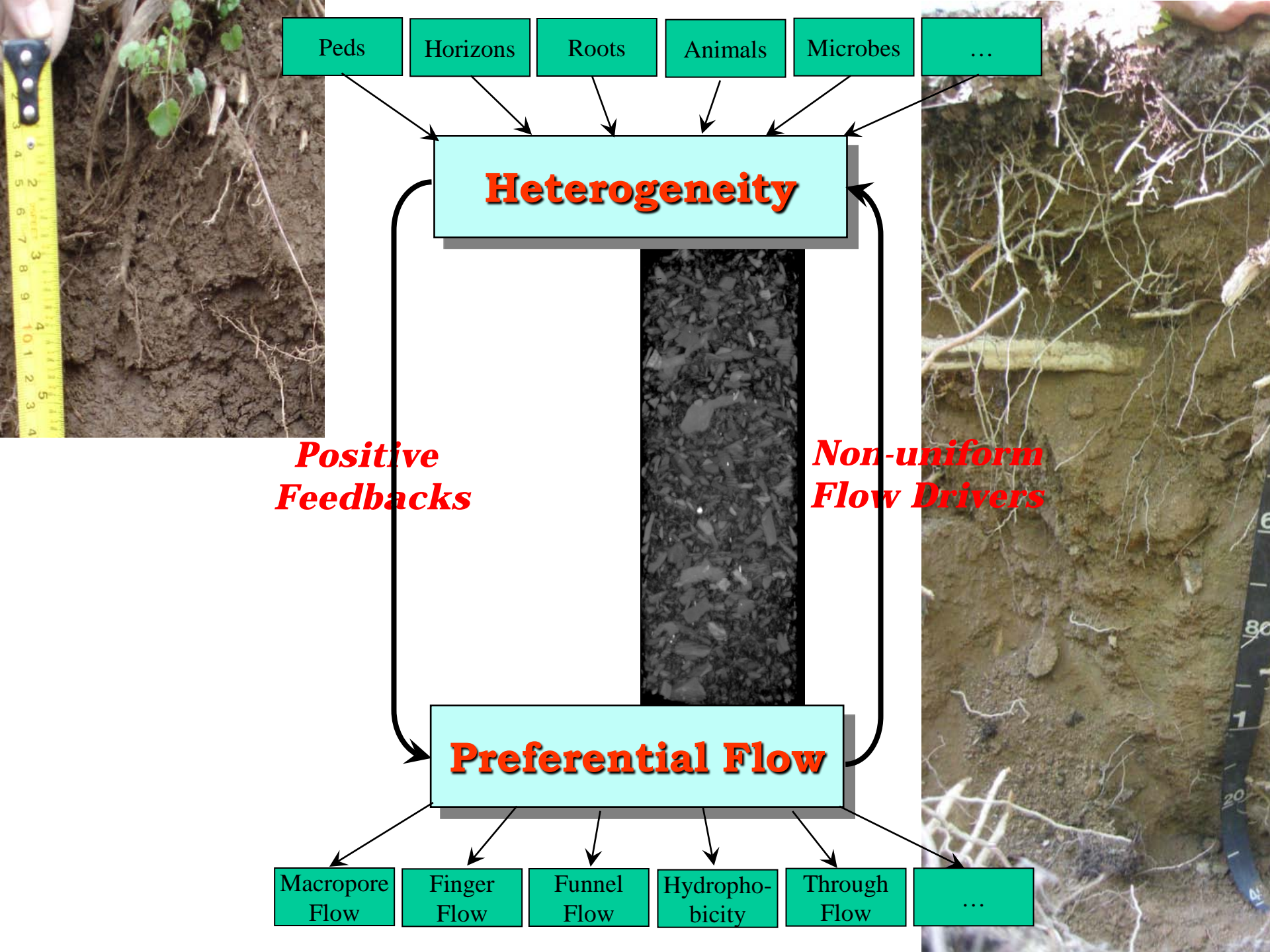


Fig. 10.9. Soil physicists who measure infiltration at the surface are not always aware of what lies hidden inside the soil profile.

(From: Hillel, 1998)



Dual-Flow Regimes

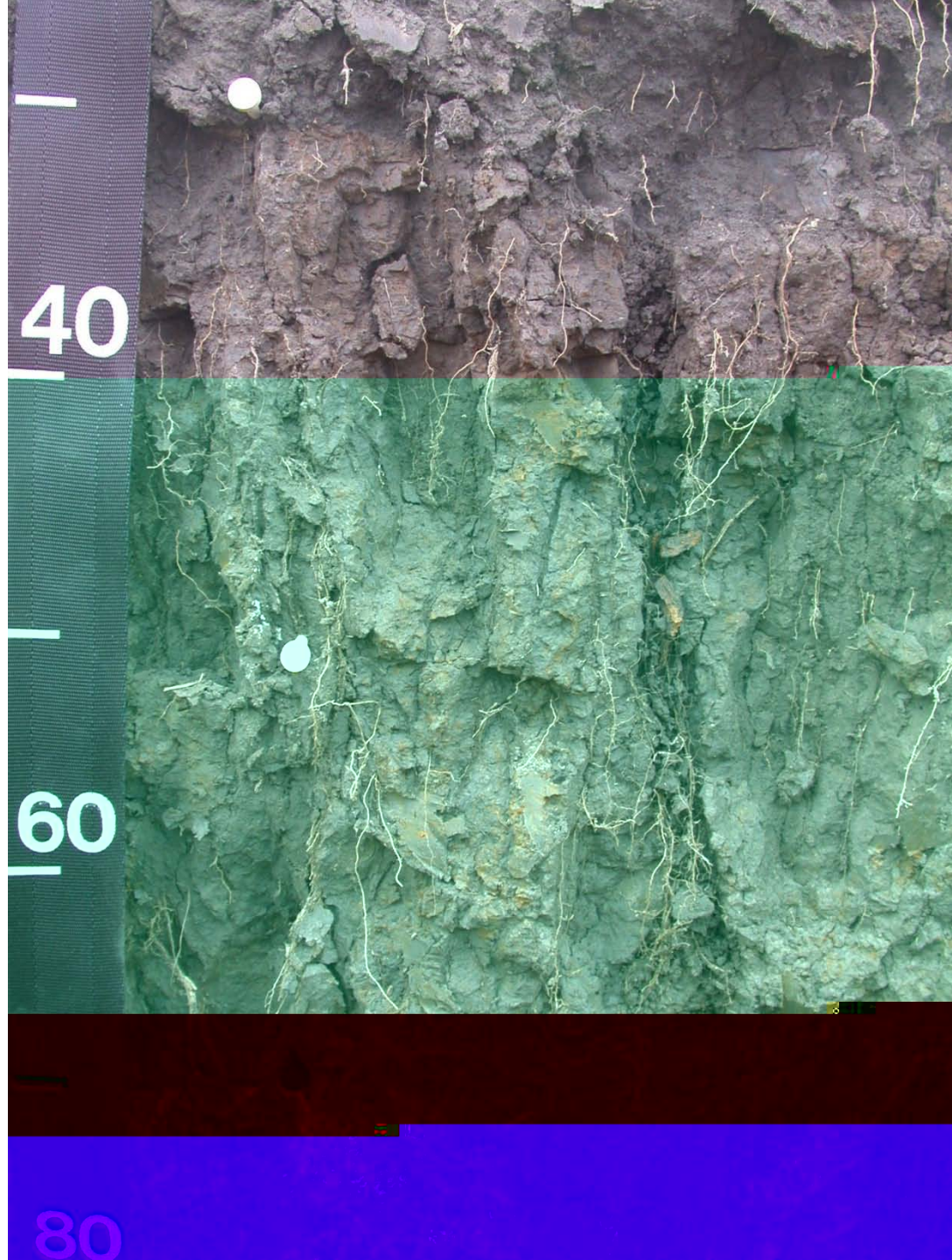
Like a “hare and tortoise” race

- **Macropores:**

Episodic, rapid spurts,
gravity-driven

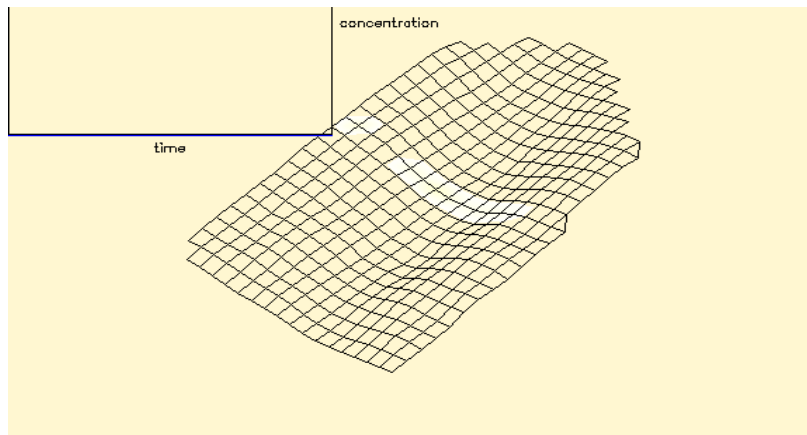
- **Micropores:**

Slow, generally
continuous (at
variable rates), driven
by hydraulic gradients
that are variably
directed

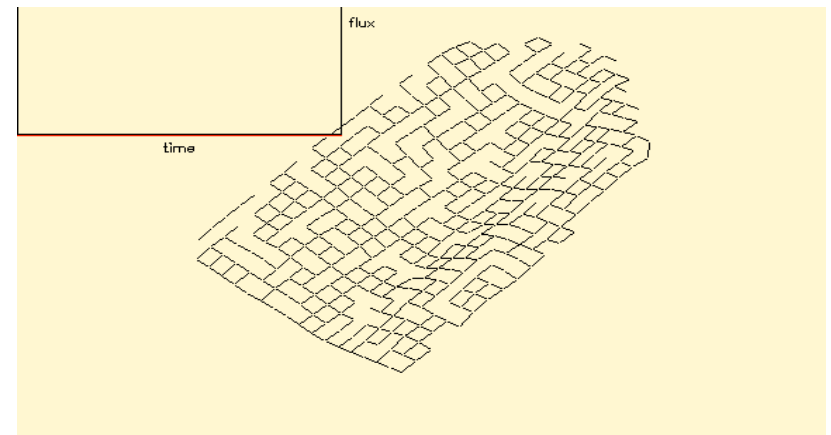


Two Flow Regimes

Piston Flow



Preferential Flow



Why Soil Architecture is Fundamental?

- Revolutionary understanding of natural systems all roots in fundamental structure: ***DNA*** for biology, ***atoms*** for physics, ***elements*** for chemistry.
- Studies of natural entities rely on fundamental structure: ***water molecular structure*** (polarity, intermolecular H bond), ***clay mineral structure*** (layer silicate, surface charge, diffuse double layer), ***humus (macro)molecular structure*** (despite extensive and important studies, the basic “backbone structure” of SOM is still an enigma).
- **My “bold” prediction:** A new era of soil science research is to be “***architecture-focused***,” passing the stage of “***texture-focused***.”

Components of Soil Architecture

- ***Pedality***: grade, size, and shape of peds
- ***Porosity***: size distribution, connectivity, tortuosity, density and morphology of pores
- ***Interfaces***: macropore-matrix interface, various coatings on peds or pores, horizon interface, soil-root interface, microbe-aggregate interface, soil-bedrock interface, soil-water table interface, etc.
- ***Biology***: root architecture, earthworm network, architecture of animal borrows, microbial distribution, etc.

Concept of Soil Architecture

- **Broad (new) vs. narrow (classical) concepts:**

- ***Soil Architecture* (a building)**
 - **Soil structure in the broadest sense**
- ***Soil Structure* (a room)**
- ***Soil Aggregation* (a desk)**

- **Across scales: Pore → pedon
→ hillslope → Catchment → ...**

Pore to Pedon Scale



Preferential flow along various macropores

- Pore-scale soil architecture

Worm Hole

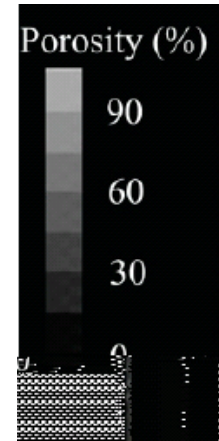
A Vertisol in Texas

(Lin et al., Adv. Agro, 2005)

An Alfisol in Pennsylvania



Soil Pore Network

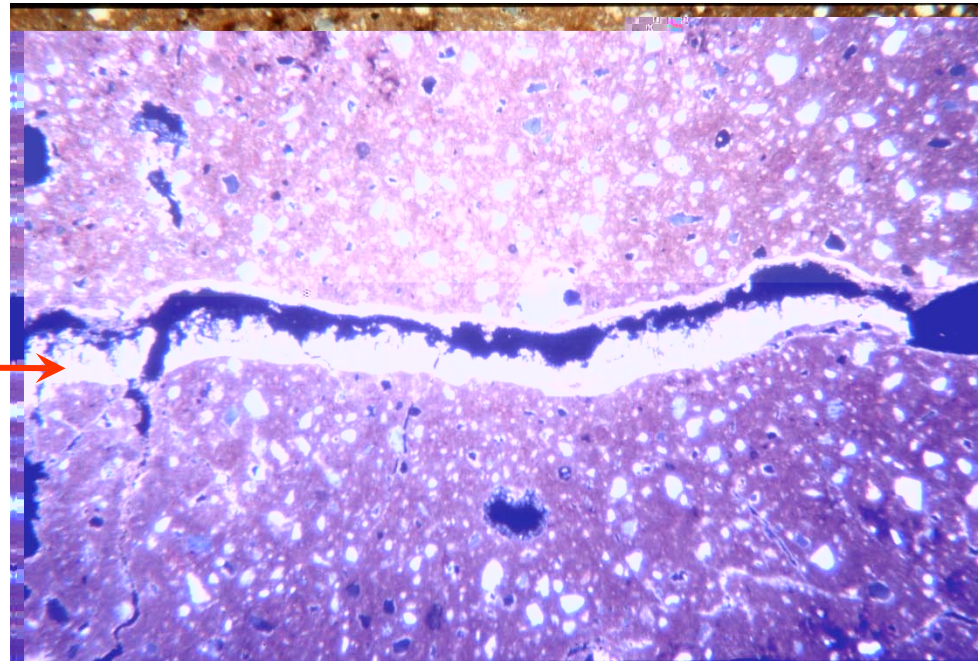


Chemical Movement

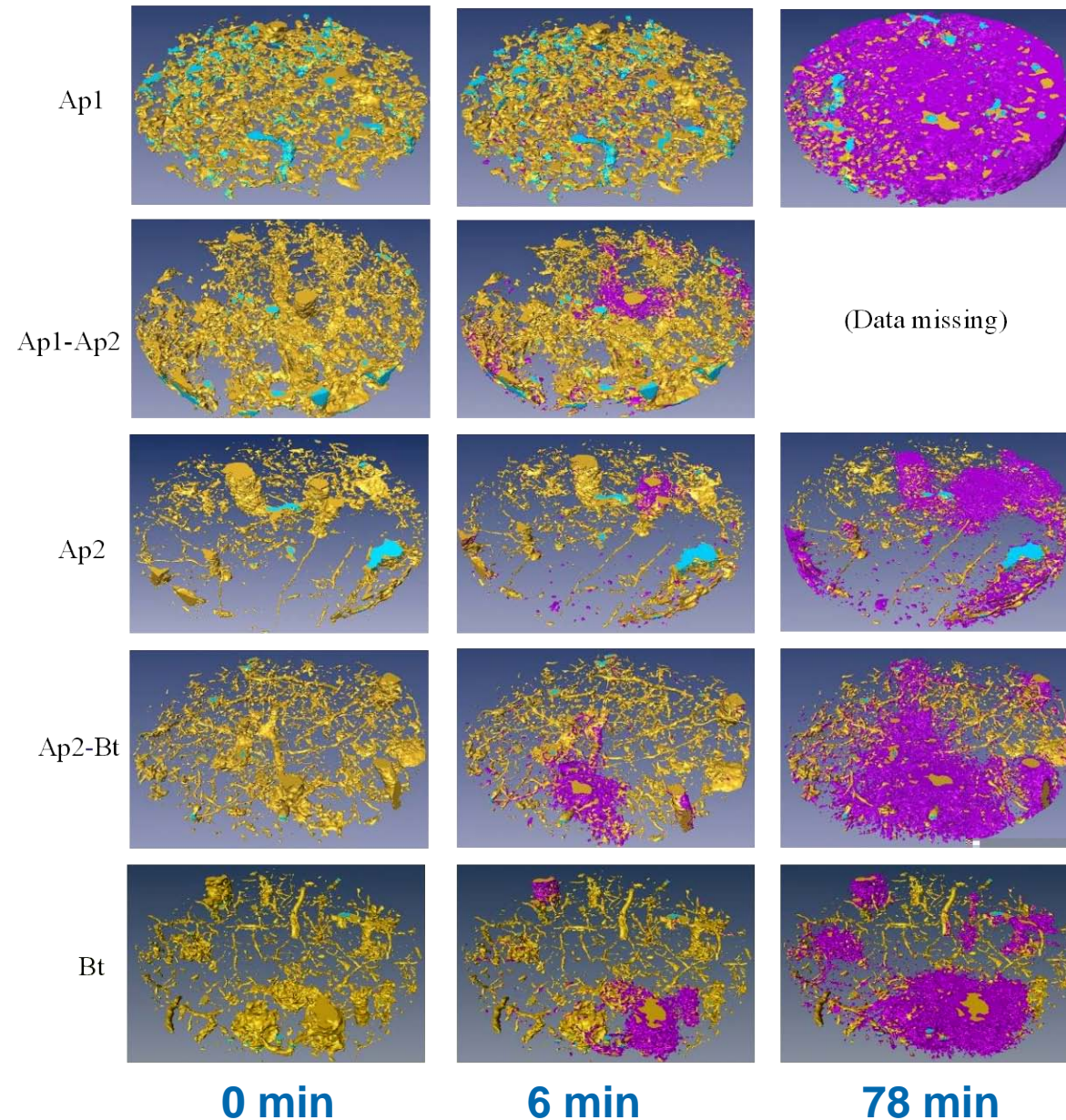
**Clay
Coating
(Cutan)**



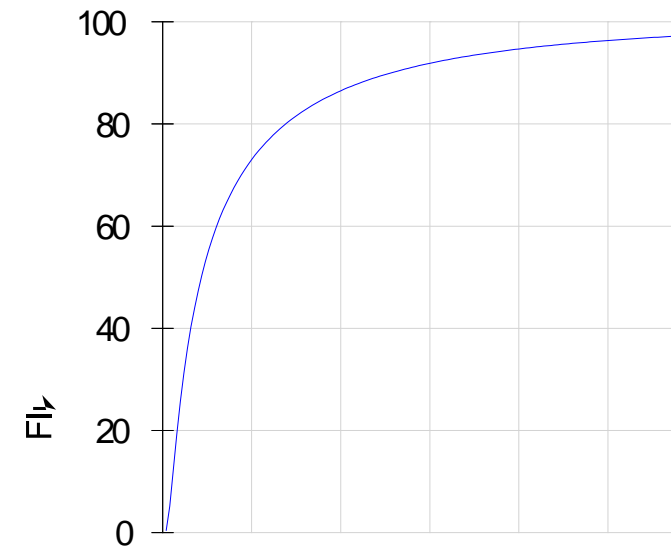
**Calcite
Coating
(Calcan)**



Macropore and tracer distribution over time in soil column



Solute distribution estimated by equilibrium model



Soil Type and Land Use Impacts

Cropland

Pasture

Hagerstown

Good structure

Fine texture

H-C

H-P

Morrison

Weak structure

Coarse texture

M-C

M-P

Soil Type and Land Use Impacts

Cropland

Pasture

Hagerstown

Good structure
Fine texture

More macropores

2.8%
(2.4-3.1%)

6.1%
(5.6-7.4%)

Morrison

Weak structure
Coarse texture

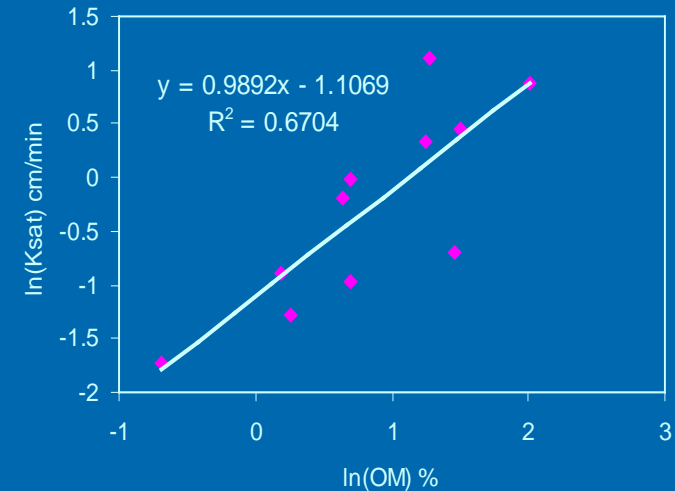
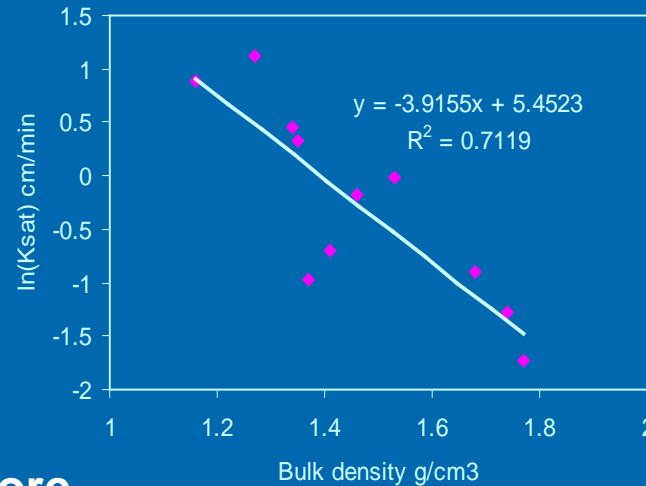
More macropores

2.4%
(2.2-2.6%)

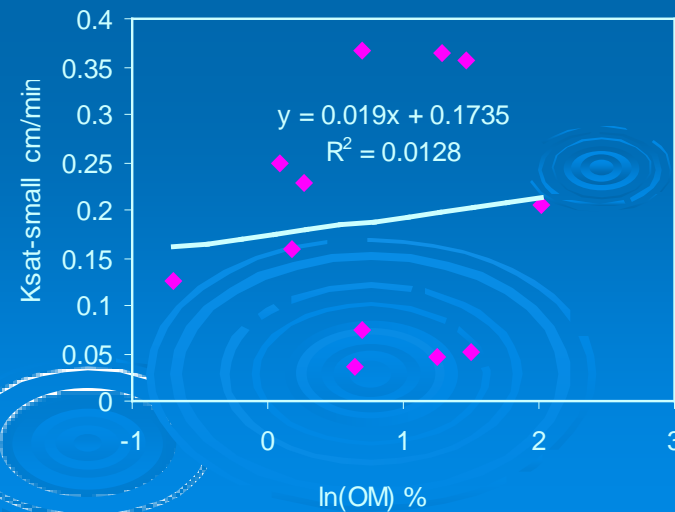
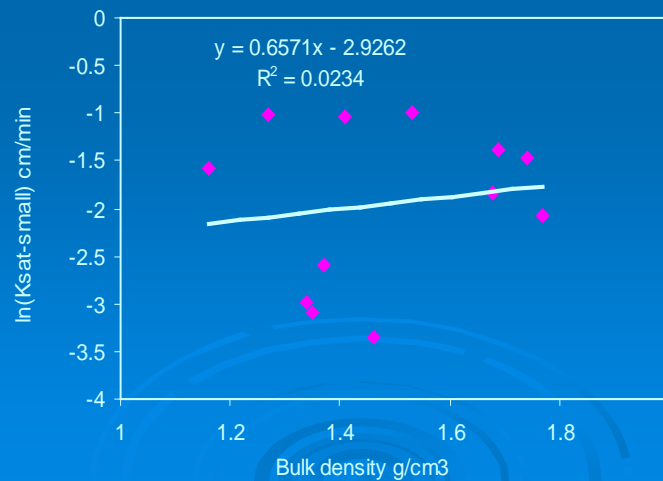
3.1%
(3.1-3.2%)

Pedotransfer function for Ksat: Issue of scale (sample size)

Ksat---soil column

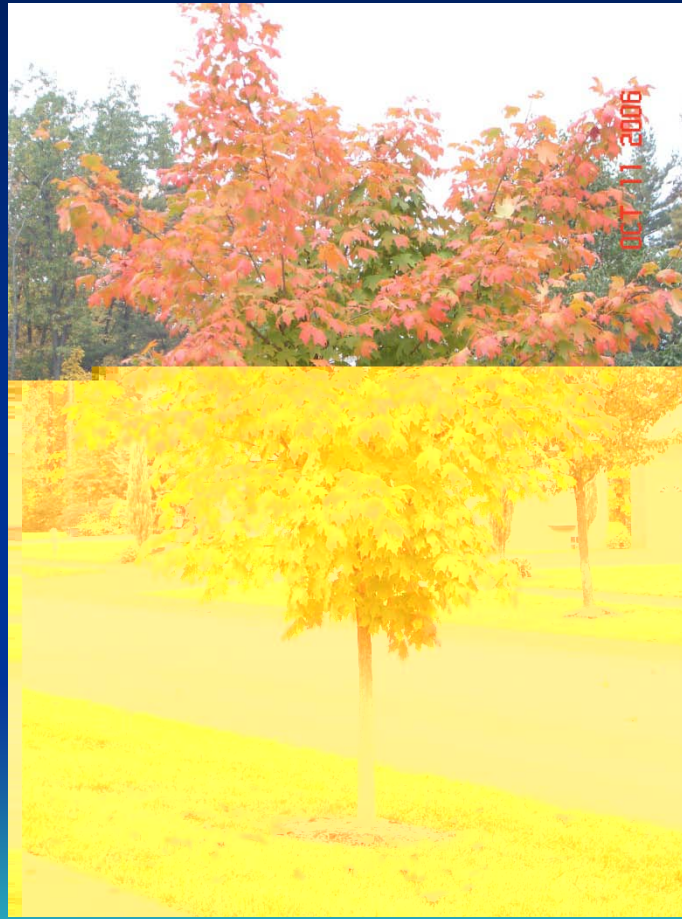


Ksat---small core

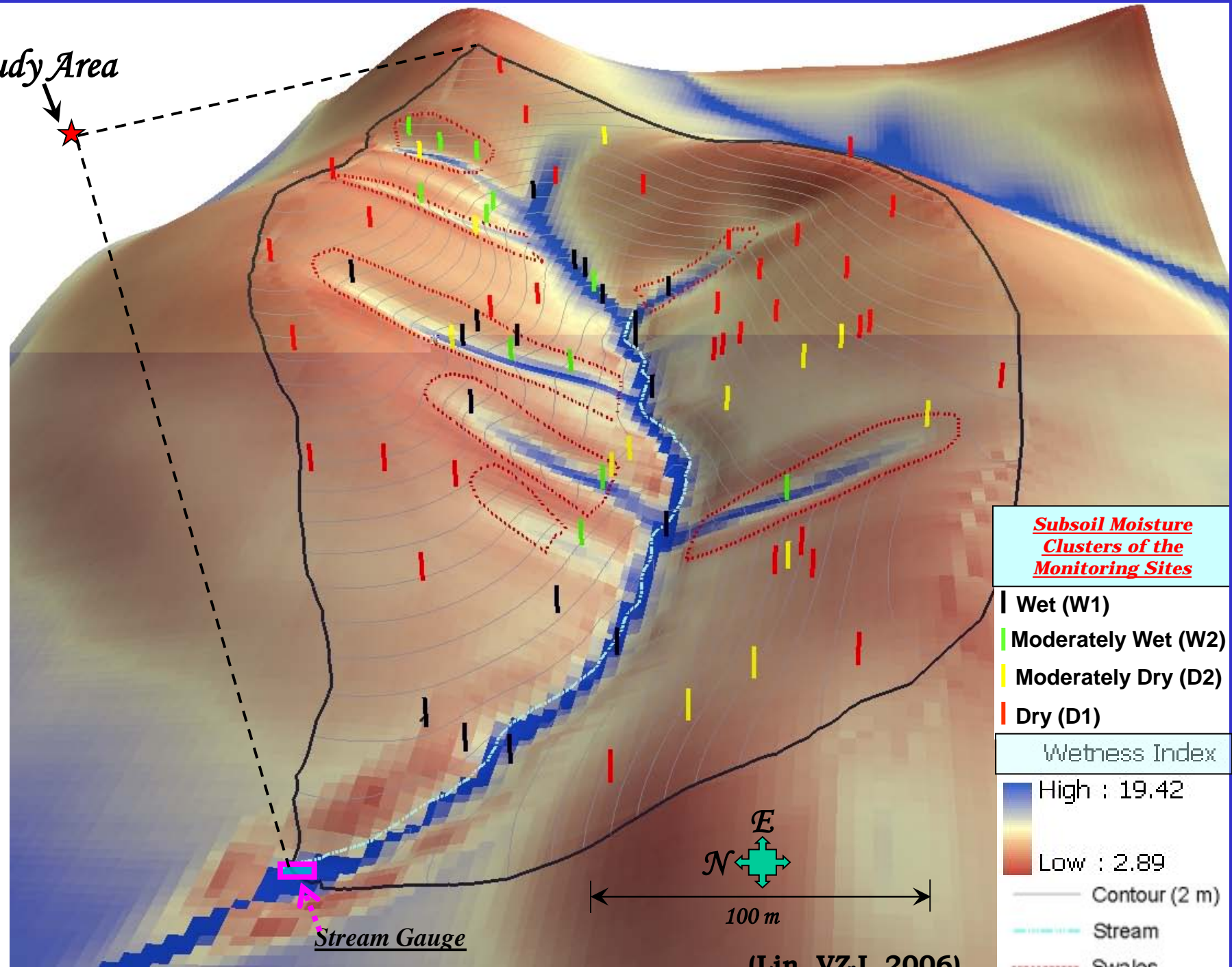




Hillslope to Landscape Scale



Study Area



Subsoil Moisture
Clusters of the
Monitoring Sites

- Wet (W1)
- Moderately Wet (W2)
- Moderately Dry (D2)
- Dry (D1)

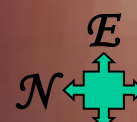
Wetness Index

High : 19.42
Low : 2.89

Contour (2 m)

Stream

Swales

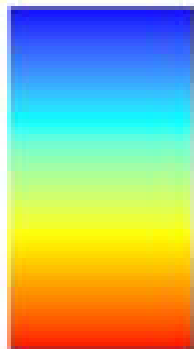


100 m

(Lin, VZJ, 2006)

Spatio-Temporal Patterns of Soil Moisture at the Catchment Scale

**Surface Soil
Moisture (%vol.)**

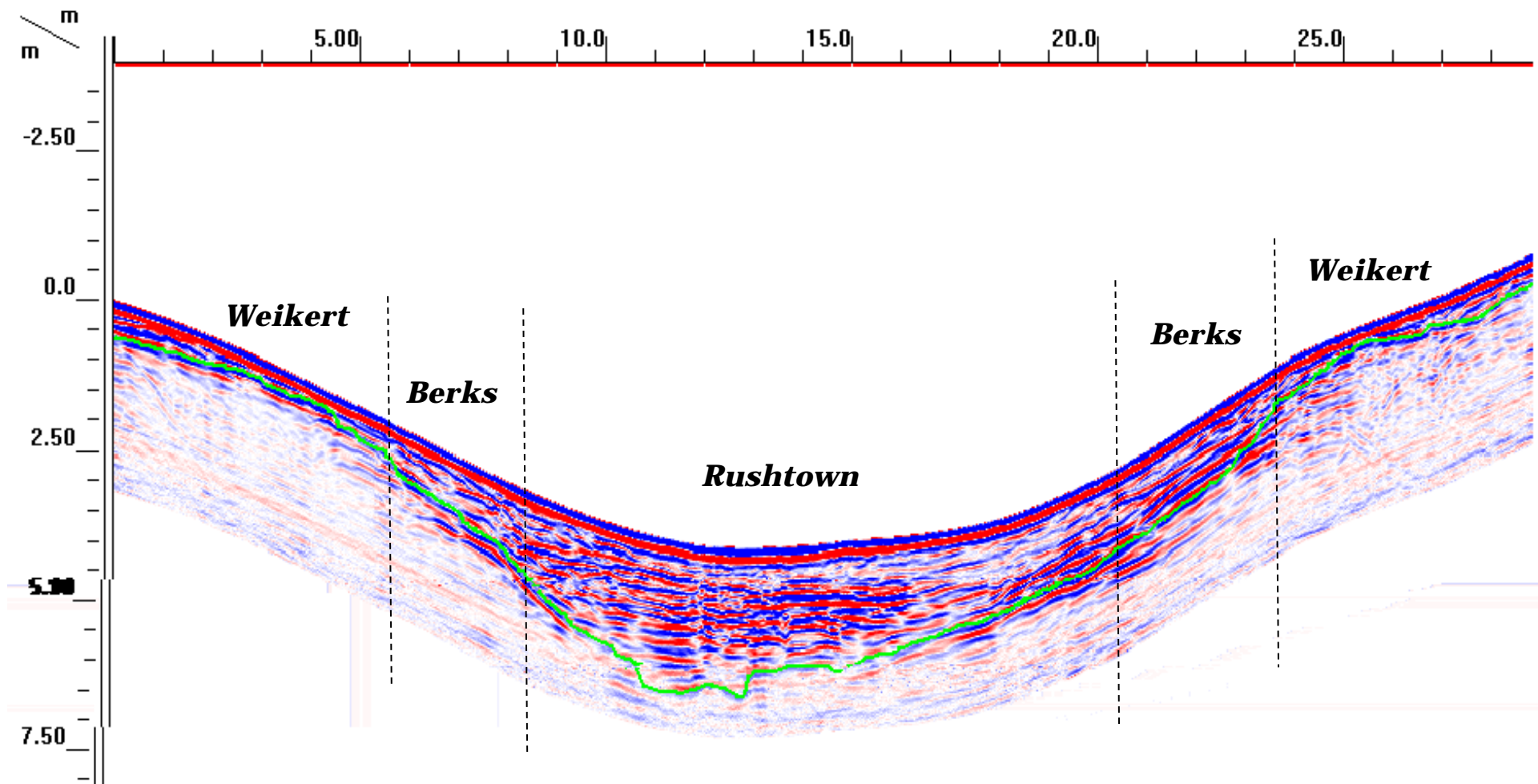


High : 60.0

Low : 5.0

(Lin et al.,
Geoderma, 2006)

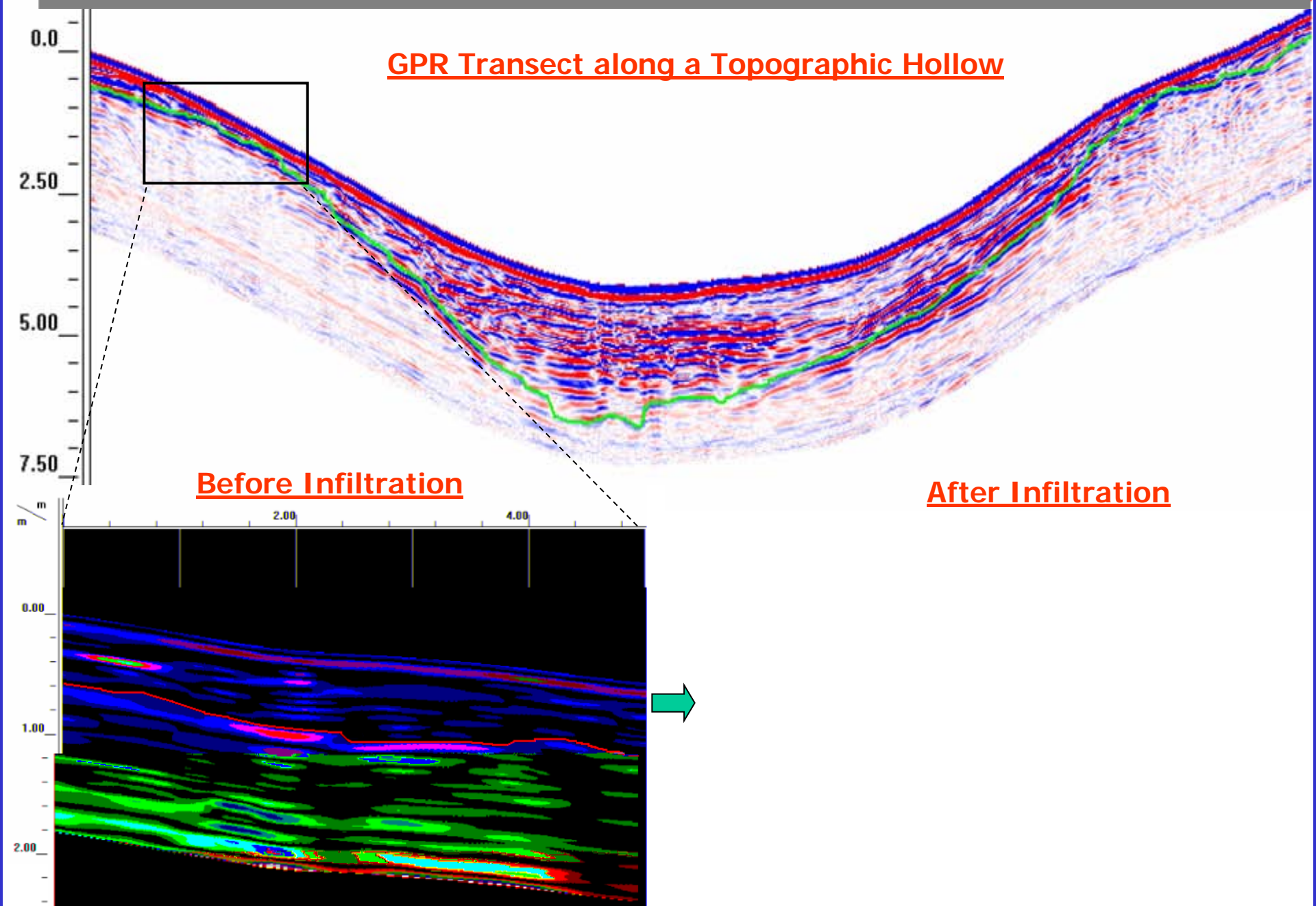
Soil Architecture at the Hillslope Scale

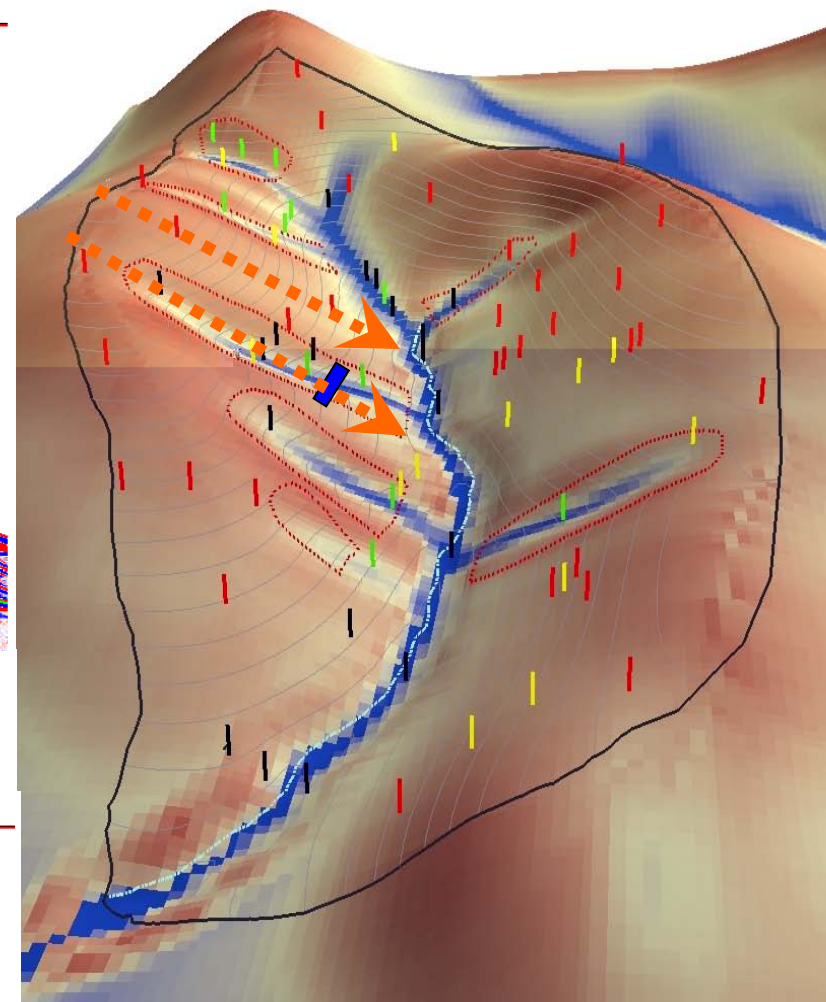
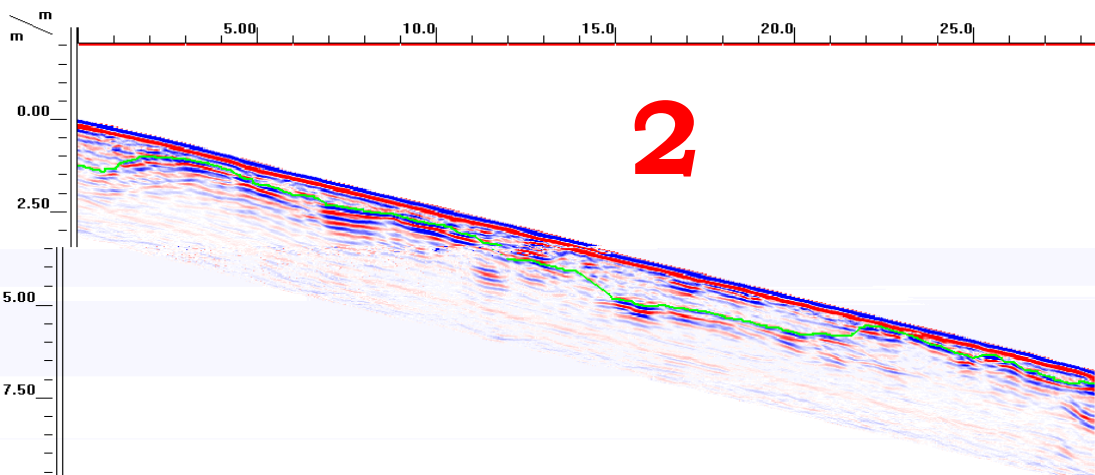
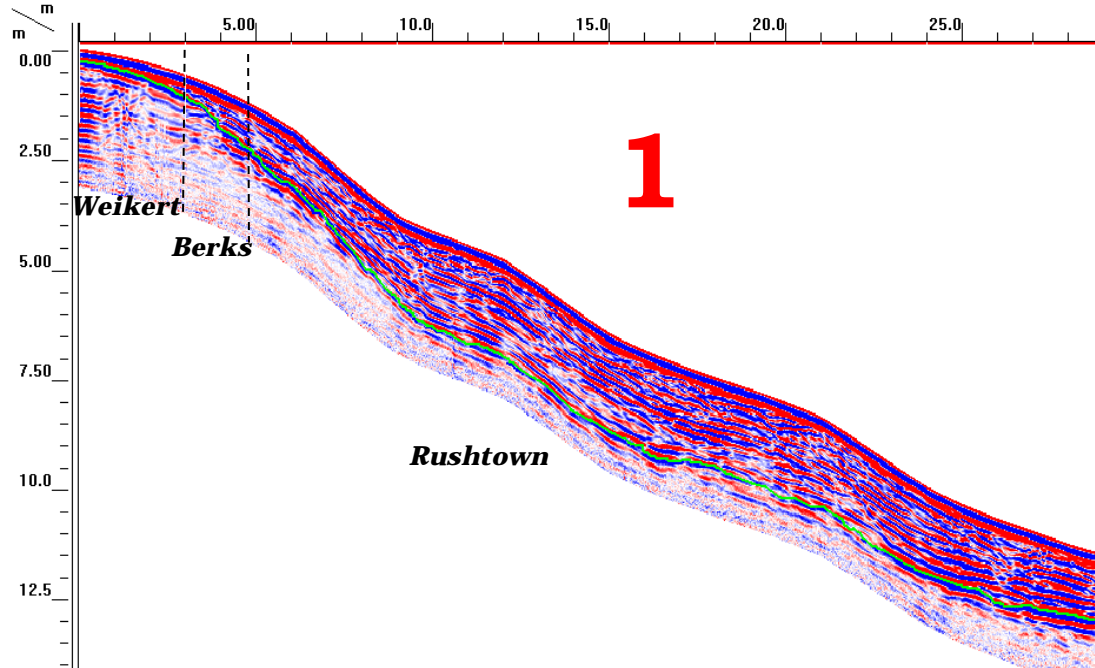


Ground-penetrating radar (GPR) image of a subsurface (a swale) in the Shale Hills Catchment. The green curve indicates an interpreted depth to bedrock. The dash lines separate 3 soil series along the hillslope.

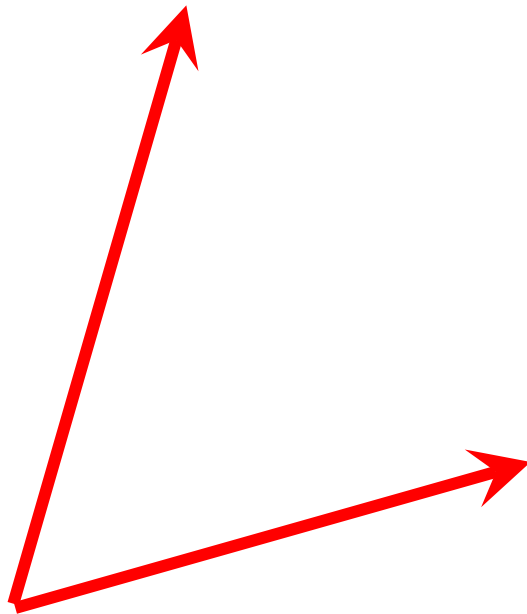
Time-lapse GPR Imaging for Detecting Subsurface Preferential Flow

GPR Transect along a Topographic Hollow





Subsurface Soil Architecture

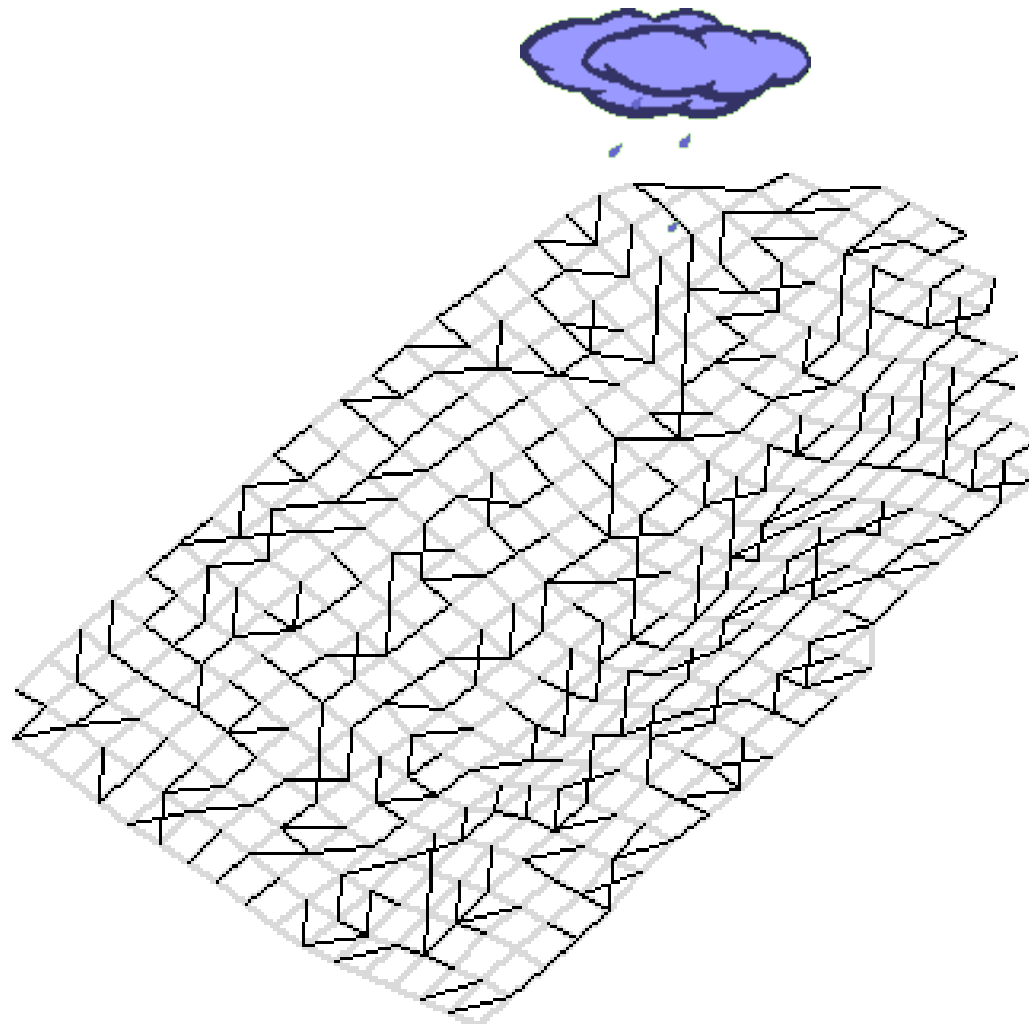


**Water-restricting soil layer
(heterogeneous, sloping)**

Critical Importance of Interfaces: Where actions and regulations occur!

Interface as a critical control:

- ***Macropore-matrix interface***: diffusion, water & ion exchange
- ***Soil horizon interface***: impedance, perched water
- ***Water-air interface***: capillarity, entrapped air
- ***Soil-root interface***: nutrient uptake, root channel as preferential flowpath
- ***Microbe-aggregate interface***: biogeochemical hot spot, denitrification microenvironment
- ***Ped interface***: chemical reaction, sorption, coatings
- ***Soil-bedrock interface***: preferential flow pathway, weathering front
- ***Soil-atmosphere interface***: evaporation, gas emission
- ***Soil-water table interface***: capillary fringe, groundwater contamination



Simulation of pipe flow in the Maimai hillslope. Black lines show the potential pipe network, whereas blue lines show the actual amount of pipe flow in the hillslope.

(Weiler and McDonnell, 2005)



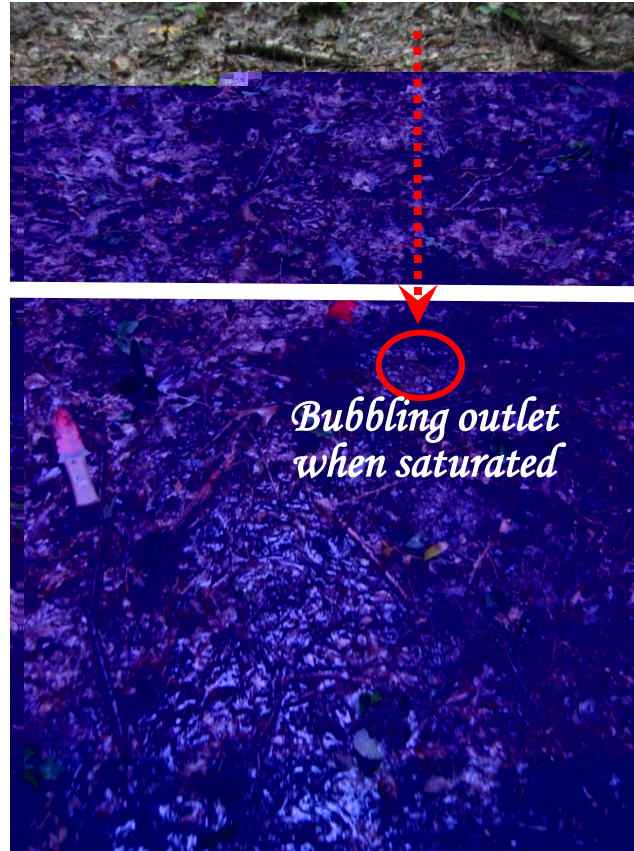
Upslope (Weikert)

Observed Preferential Flow Pathways along the Shale Hills Hillslope

Midslope (Berkş)

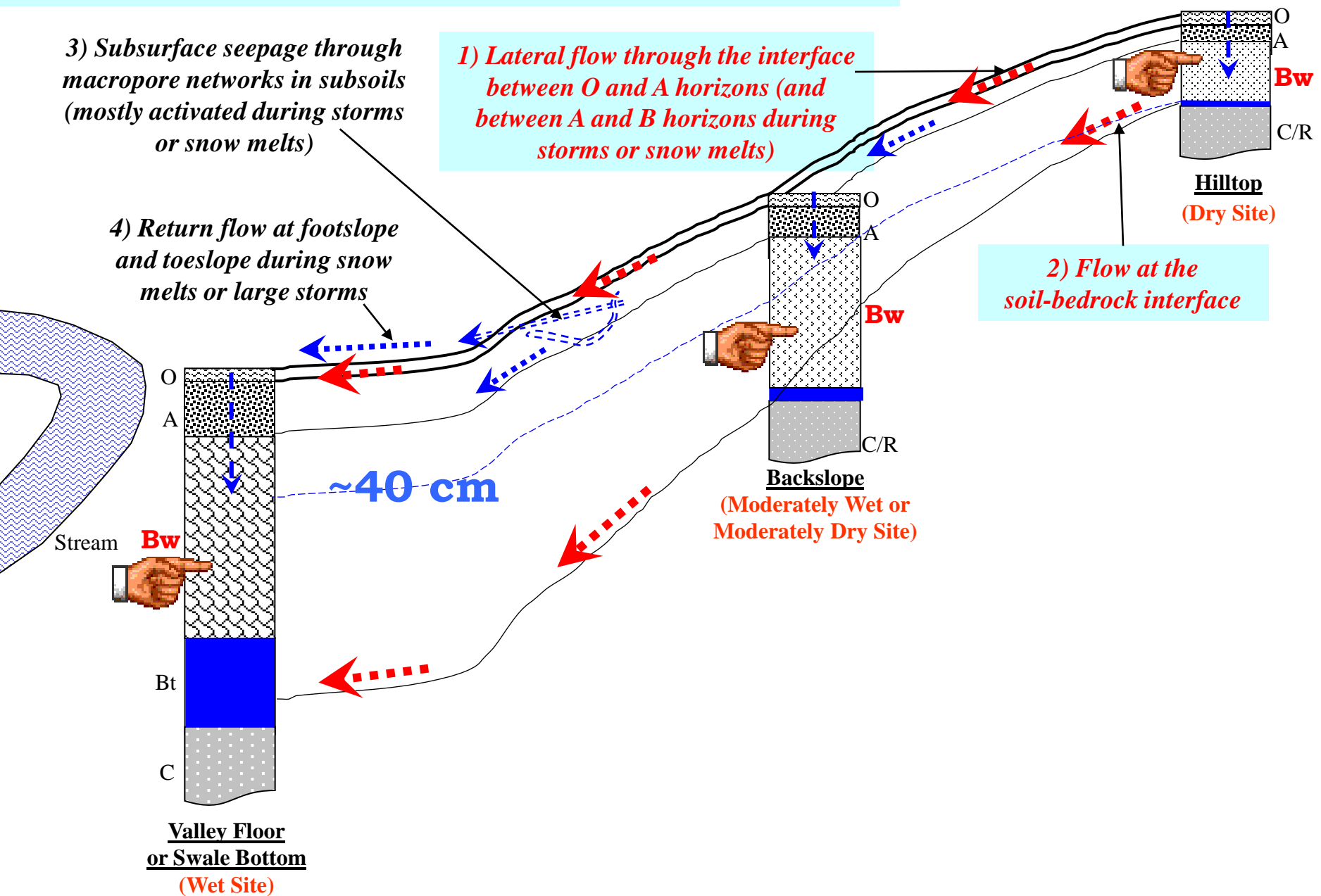
Downslope (Ernest)

*Surface runoff at footslope
near the stream*



*Flow at the interface between the
Weikert soil and the fractured shale*

Main flow paths along the hillslope at the Shale Hills



Lightning network

Leaf vein network

Landscape drainage network

Dry soil cracking network

Hidden Networks Belowground



Preferential flow network

Root branching network

Mycorrhizal fungi network

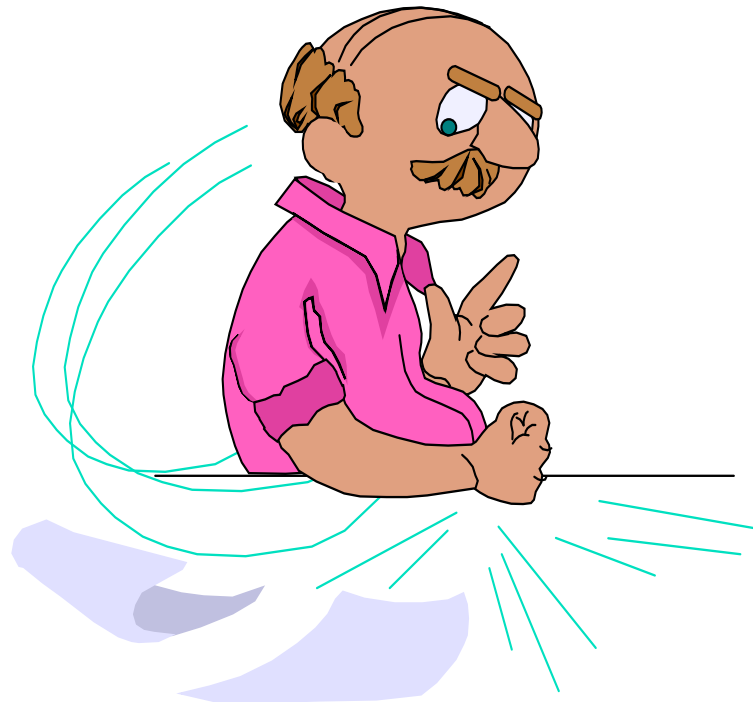
Earthworm borrowing network

Electrifying take-off?!









Pay serious attention to:

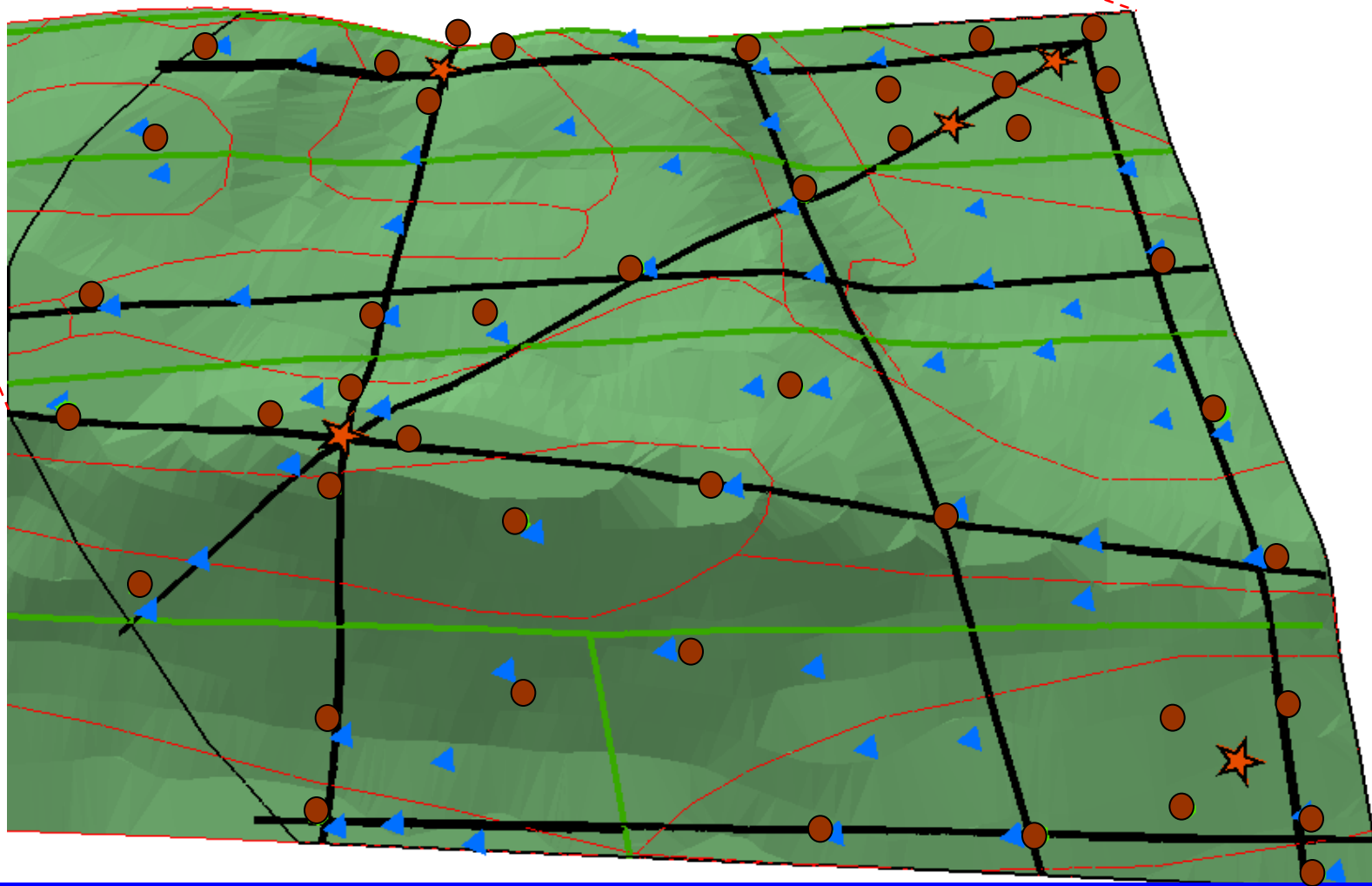
**Soil Architecture &
Preferential Flow!**

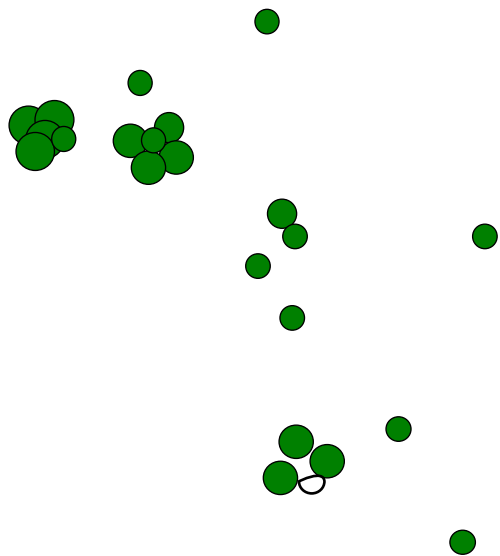




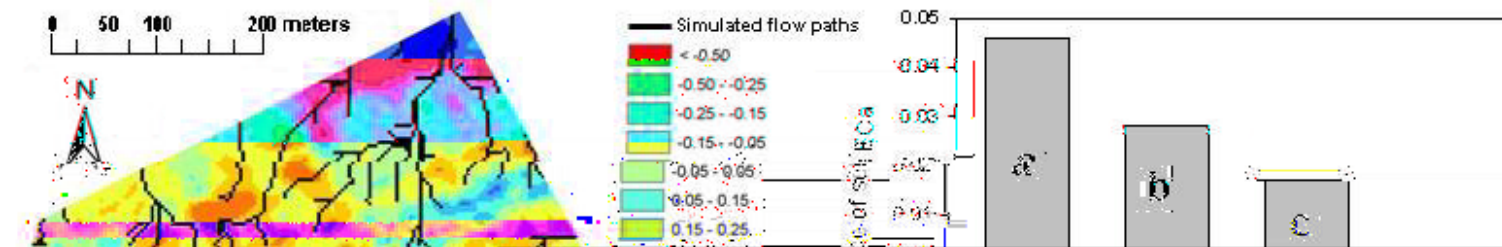
Legend

-  Super site
-  Key site
-  Satellite site
-  Transect
-  Soil Boundary
-  Crop Boundary





a) Relative difference of soil ECa for EM38V surveys conducted on 16 January and 10 March 2008 (a wetter period)



Soil Mn contents on and off water flow paths in an agricultural landscape

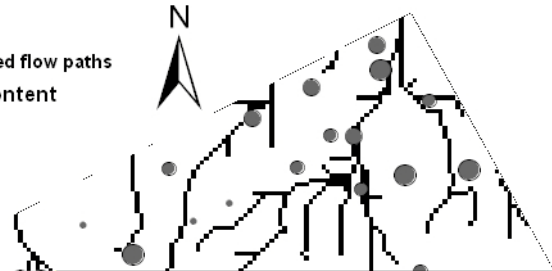
At clay layer interface

Legend

— Simulated flow paths

Mn mottle content

- <1%
- 1-2%
- 2-5%
- >5%



At soil-bedrock interface

